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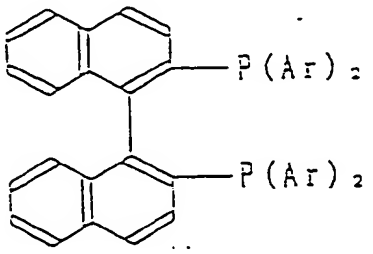
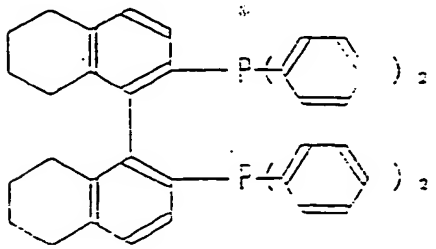
(54) Iridium-optically active phosphine complex and catalytic production of optically active alcohols therewith.

(57) An iridium-optically active phosphine complex is represented by the formula : $[H_2Ir(L^1)(L^2)]Y$ wherein L^1 is an optically active phosphine compound (II) or (III) :



(II)

wherein Ar is a phenyl group or a p- and/or m-lower (C1-4) alkyl-substituted phenyl group :



(III)

e.g. BINAP,
L^2 is a tertiary phosphino compound of formula (IV) :

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The present invention relates to a novel iridium-phosphine complex useful as a catalyst for various organic syntheses, particularly enantioselective hydrogenation reactions, and to a process for producing optically active alcohols using the complex.

A number of organic synthesis reactions using a transition metal complex as a catalyst have hitherto been developed and made use of for various purposes. In particular, many reports have been made on enantioselective catalysts useful for enantioselective synthesis reactions, such as enantioselective hydrogenation and enantioselective isomerization. Among them, metal complexes in which an optically active tertiary phosphine compound is coordinated to metallic rhodium or ruthenium are well known as catalysts for enantioselective hydrogenation.

For example, a rhodium-phosphine complex using 2,2'-bis(diphenylphosphino)-1,1'-binaphthyl (hereinafter abbreviated as BINAP) as a ligand is disclosed in JP-A-55-61937 (the term "JP-A" as used herein means an "unexamined published Japanese patent application").

Known ruthenium complexes include those having BINAP or a derivative thereof as a ligand, such as $Ru_2Cl_4(BINAP)_2$ (NEt_3) (wherein Et represents an ethyl group) as disclosed in Ikariya, et al., J. Chem. Soc., Chem. Commun., p. 922 (1985), $Ru(O_2CR)_2$-(BINAP) (wherein R represents a lower alkyl group, a lower alkyl-substituted phenyl group, etc.) as disclosed in JP-A-62-265293, and $[RuH_\ell(R\text{-}BINAP)_m]X_n$ (wherein R represents a hydrogen atom or a methyl group; X represents $c\ell O_4$, BF_4, or PF_6; when ℓ is 0, m represents 1, and n represents 2; and when ℓ is 1, m represents 2, and n represents 1) as disclosed in JP-A-63-41487.

For further information on enantioselective synthesis reactions using transition metal catalysts, Sheri. L. Blystone, Chemical Reviews, pp. 1663-1679 (1989) can be referred to.

However, few cases are known in which an iridium-optically active phosphine complex is actually used as a catalyst for enantioselective syntheses, except conversion of an imine to an optically active amine as reported, e.g., in JP-A-63-57558 and JP-A-64-47723.

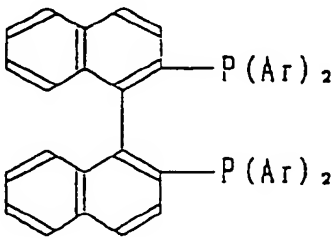
Rhodium- or ruthenium-optically active phosphine complexes are known to exhibit high catalytic activity on a relatively wide range of substrates to give a high enantioselectivity (i.e., optical purity of a product) in enantioselective syntheses, especially enantioselective hydrogenation. However, both the catalytic activity and enantioselectivity achieved by these complexes are sometimes unsatisfactory depending on the reaction substrate. Accordingly, there has been a need for a novel catalyst for enantioselective syntheses.

In order to meet the above-described need, the inventors have conducted extensive studies and, as a result, have found a novel iridium-optically active phosphine complex which exhibits excellent catalytic activity and gives high enantioselective yields in enantioselective syntheses, particularly enantioselective hydrogenation.

The present invention relates to an iridium-optically active phosphine complex represented by formula (I):

$$[H_2Ir(L^1)(L^2)]Y \quad (I)$$

wherein L^1 represents an optically active phosphine compound represented by formula (II):



(II)

wherein Ar represents a phenyl group or a p- and/or m-lower alkyl-substituted phenyl group (the lower alkyl moiety thereof preferably containing from 1 to 4 carbon atoms),
or formula (III):

$$[Ir(COD)(CH_3CN)_2]Y \qquad (VII)$$

$$\downarrow L^1$$

$$[Ir(COD)(L^1)]Y \qquad (VIII)$$

$$\downarrow L^2$$

$$\downarrow H^2$$

$$[H_2Ir(L^1)(L^2)]Y \qquad (I)$$

wherein COD represents 1,5-cyclooctadiene; and L^1, L^2, and Y are as defined above.

That is, a complex of formula (VII) is reacted with an optically active phosphine compound L^1 to obtain a complex of formula (VIII), which is then reacted with a tertiary phosphine compound L^2 and hydrogen to obtain the iridium-optically active phosphine complex (I) of the present invention.

The starting complex (VII) can be prepared according to the process disclosed in M. Green, et al., J. Chem. Soc., (A) 2334 (1971).

Of the starting optically active phosphine compounds L^1, the optically active compound of formula (III), i.e., 2,2'-bis(diphenylphosphinyl)-5,5',6,6',7,7',8,8'-octahydro-1,1'-binaphthyl (hereinafter abbreviated as OcH-BINAP) can be synthesized, for example, as follows. 2,2'-Dibromo-1,1'-binaphthyl synthesized by the process disclosed in H. Takaya, et al., J. Org. Chem., Vol. 51, p. 629 (1986) is hydrogenated in the presence of a ruthenium-on-carbon catalyst to obtain 2,2'-dibromo-5,5',6,6',7,7',8,8'-octahydro-1,1'-binaphthyl (2,2'-dibromo-1,1'-bitetrahydronaphthalene), which is then reacted with metallic magnesium to form a Grignard reagent. The resulting Grignard reagent is condensed with diphenylphosphinyl chloride to synthesize racemic OcH-BINAP. The racemate is optically resolved by recrystallization from a mixed solvent of chloroform and ethyl acetate in the presence of optically active dibenzoyltartaric acid as a resolving agent, and the precipitated crystal collected by filtration is treated with 1N sodium hydroxide to obtain a phosphine oxide. The optical purity of the phosphine oxide is determined by high performance liquid chromatography using an optically active column, and the above recrystallization operation is repeated until the product becomes optically pure. The thus obtained optically active phosphine oxide is then reduced by using trichlorosilane to obtain optically active OcH-BINAP.

The reaction between the complex (VII) and the optically active phosphine compound L^1 can usually be carried out by stirring in a solvent, e.g., tetrahydrofuran and methylene chloride, at room temperature for 20 minutes to 1 hour. The reaction between the complex (VIII) and the tertiary phosphine compound L^2 can usually be carried out by stirring in a solvent, e.g., tetrahydrofuran and methylene chloride, in a hydrogen gas atmosphere at room temperature for 5 to 30 hours.

The thus produced iridium-optically active phosphine complex (I) can be used as a catalyst for enantioselective syntheses either in the form of the reaction mixture as produced or after being isolated therefrom.

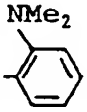
Examples of enantioselective hydrogenation reactions to which the complex of the present invention is applicable are described below.

Enantioselective hydrogenation of 3-oxotetrahydrothiophene in the presence of the complex (I) gives optically active 3-hydroxytetrahydrothiophene. In carrying out the reaction, the substrate, 3-oxotetrahydrothiophene, is dissolved in an appropriate solvent, e.g., methanol, tetrahydrofuran, methylene chloride, benzene or a mixture thereof, the complex (I) is added to the substrate solution in an amount of from 1/1000 to 1/10 mole per mole of the substrate, and the reaction system is maintained at a temperature of from 10 to 50°C, and preferably around 30°C, under a hydrogen pressure of from 2 to 100 kg/cm^2, and preferably from 30 to 50 kg/cm^2.

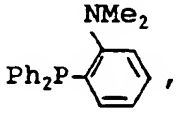
Enantioselective hydrogenation of an α,β-unsaturated ketone of formula (V) in the presence of the complex (I) yields an optically active allyl alcohol derivative of formula (VI) as illustrated by the following reaction scheme:

^{31}P-NMR ($CDC\ell_3$) δ ppm: 14.9 (s)
^{1}H-NMR ($CDC\ell_3$) δ ppm: 3.95 (m, 2H), 4.26 (m, 2H), 6.94 (d, 2H), 7.32 (q, 4H), 7.40 (d, 2H), 7.54 (m, 16H)

EXAMPLE 1

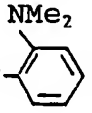
Synthesis of $[H_2Ir(Ph_2P$-  $)((+)\text{-BINAP})]BF_4$

In a 50 mℓ flask with side-arm were charged 252.2 mg (0.25 mmole) of [Ir(COD)((+)-BINAP)]BF_4 synthesized in Reference Example 1 and 80.06 mg (0.263 mmole) of



and 5 mℓ of tetrahydrofuran was added thereto. The reaction mixture was stirred in a hydrogen atmosphere at room temperature for 18 hours, followed by concentration to dryness to obtain 302 mg of the titled compound.
^{1}H-NMR (CD_3CN) δ ppm: -11.51 to -11.49 (m, 1H), -9.04 to -8.71 (m, 1H), 1.45 to 2.54 (6H, N-Me), 5.60 to 8.50 (46H, aromatic ring)
Elemental Analysis for $C_{64}H_{54}BF_4NP_3Ir$:
Calcd. (%): C 63.58; H 4.50; N 1.16
Found (%): C 63.61; H 4.39; N 1.42

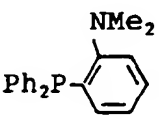
EXAMPLE 2

Synthesis of $[H_2Ir(Ph_2P$-  $)((-)\text{-OcH-BINAP})]BF_4$

The titled complex was prepared in the same manner as in Example 1, except for replacing (+)-BINAP with (-)-OcH-BINAP.
^{1}H-NMR (CD_3CN) δ ppm: -11.73 to -11.35 (m, 1H), -9.38 to -9.06 (m, 1H), 2.04 to 2.50 (6H, N-Me), 1.60 to 2.80 (16H, methylene group), 6.00 to 8.40 (38H, aromatic ring)
Elemental Analysis for $C_{64}H_{66}BF_4NP_3Ir$:
Calcd. (%): C 62.95; H 5.45; N 1.15
Found (%): C 62.73; H 5.14; N 1.08

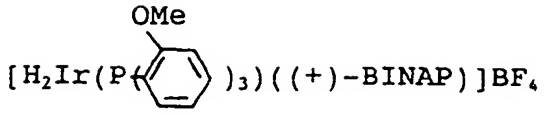
EXAMPLES 3 TO 8

The following complexes were prepared in the same manner as in Example 2, except for replacing (-)-OcH-BINAP with (+)-BINAP, (-)-Tol-BINAP or (-)-2,2′-bis{di(3,5-dimethylphenyl)phosphino}-1,1′-binaphthyl (hereinafter abbreviated as (-)-3,5-D,M-BINAP) and replacing



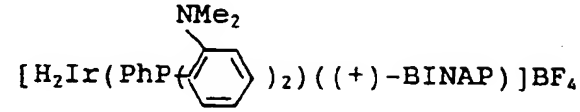
with

Example 7:



Elemental Analysis for $C_{66}H_{55}BF_4O_3P_3Ir$:
Calcd. (%): C 62.15; H 4.41
Found (%): C 62.41; H 4.62

Example 8:

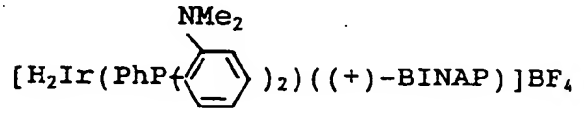


Elemental Analysis for $C_{66}H_{59}N_2P_3BF_4Ir$:
Calcd. (%): C 63.31; H 4.75; N 2.24
Found (%): C 63.53; H 4.46; H 2.19

EXAMPLE 9

Enantioselective Hydrogenation of 3-Oxotetrahydrothiophene

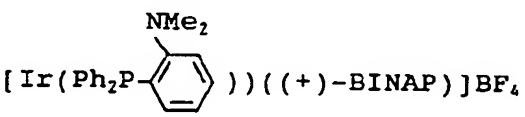
In a 500 mℓ stainless steel autoclave were charged 214.5 g (2.103 mole) of 3-oxotetrahydrothiophene and 13 g (10.5 mmole) of



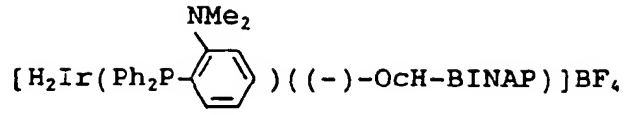
synthesized in Example 8 in a nitrogen atmosphere, and 200 mℓ of tetrahydrofuran and 43 mℓ of methanol were added thereto, followed by stirring at 30°C for 45 hours under a hydrogen pressure of 50 kg/cm². The reaction mixture was concentrated, and the residue was subjected to silica gel column chromatography (eluent: hexane/benzene/ethyl acetate=70/25/10 by volume) to separate the hydrogenation product from the unreacted matter. There were recovered 146 g of the unreacted matter and 63 g of 3-hydroxytetrahydrothiophene (conversion: 31.8%; theoretical percent yield: 93.8%).
$[\alpha]_D^{25}$: +9.2° (c=2.r, $CHC\ell_3$)
Optical purity: 63.2 %ee

EXAMPLE 10

In a 100 mℓ stainless steel autoclave were charged 3 mℓ (35.1 mmole) of 3-oxotetrahydrothiophene and 0.121 g (0.176 mmole) of



synthesized in Example 2 in a nitrogen atmosphere, and 3 mℓ of tetrahydrofuran and 1 mℓ of methanol were added thereto. The mixture was stirred at 30°C under a hydrogen pressure of 50 kg/cm² for 45 hours, and the reaction mixture was worked up in the same manner as in Example 9 to obtain 0.84 g of 3-hydroxytet-



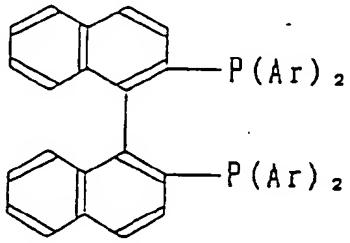
synthesized in Example 2, 1.68 g of an allyl alcohol having a purity of 90% and an optical purity of 68 %ee was obtained at a conversion of 30%.

Claims

1. An iridium-optically active phosphine complex represented by formula (I):

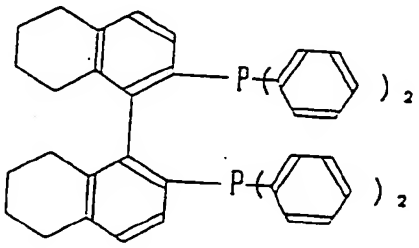
$$[H_2Ir(L^1)(L^2)]Y \quad (I)$$

wherein L^1 represents an optically active phosphine compound represented by formula (II):



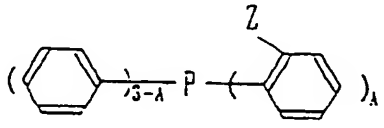
(II)

wherein Ar represents a phenyl group or a p- and/or m-lower alkyl-substituted phenyl group, or formula (III):



(III)

L^2 represents a tertiary phosphine compound represented by formula (IV):



(IV)

wherein Z represents a lower alkoxy group or a di-lower alkylamino group and A represents an integer of from 1 to 3; and Y represents BF_4, PF_6, $C\ell O_4$ or BPh_4, wherein Ph represents a phenyl group.

2. A process for producing an optically active 3-hydroxytetrahydrothiophene comprising enantioselective hydrogenation of 3-oxotetrahydrothiophene in the presence of an iridium-optically active phosphine complex represented by formula (I):

$$[H_2Ir(L^1)(L^2)]Y \quad (I)$$

as defined in Claim 1.

3. A process for producing an optically active allyl alcohol derivative represented by formula (VI):

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 91 30 8956

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	EP-A-0 104 376 (F. HOFFMANN-LA ROCHE AND CO.) * the whole document * ---	1,3	C07F15/00 C07C29/00 B01J31/00
D,A	EP-A-0 245 959 (TAKASAGO PERFUMERY CO. LTD) * the whole document * ---	1,3	
A	GB-A-1 135 979 (IMPERIAL CHEMICAL INDUSTRIES LTD) * the whole document * ---	1,3	
A	US-A-4 924 029 (HARSY, S.G.) * the whole document * -----	1,3	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)
C07F C07C B01J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	21 NOVEMBER 1991	RINKEL L.J.

CATEGORY OF CITED DOCUMENTS

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